

Evidence for an Early Delta of the Detroit River in Western Lake Erie¹

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ABSTRACT. Test borings in the western basin of Lake Erie have revealed an extensive sub-bottom deposit of sand in a triangular region bounded by Stony Point on the mainland shore of Michigan, Middle Sister Island in Ontario, and West Sister Island in Ohio. The 550 km² deposit is overlain by up to 7 m of more recent lacustrine silts and clays. The sand beds have an average thickness of 2.3 m, yielding a total volume of approximately 1.3×10^9 m³ of sand. A preliminary interpretation is that when the ancestral Detroit River first flowed into Early Lake Erie about 4-5,000 years B. P. deltaic sediments were deposited in the northern portion of the western basin. The material of these beds is primarily a clean, medium- to fine-grained, moderately well-sorted sand that appears to have commercial extraction quality.

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INTRODUCTION

In contrast to ocean shorelines, coastal deposition processes which produce subaerial landforms such as a delta are not common in the Great Lakes. With the exception of the St. Clair River delta in Lake St. Clair, and possibly the Niagara River delta in Lake Ontario, no other significant deltas occur in the modern Great Lakes. The combination of a shallow receiving basin and an abundant supply of sandy sediment is largely responsible for the deposition of the St. Clair delta (Herdendorf et al. 1986). However, evidence from test borings in western and central Lake Erie suggests that massive deltas were also formed during the low water levels of an early Lake Erie.

Sand and gravel resources in the Lake Erie basin are generally restricted to nearshore littoral deposits and offshore glacial moraines. A survey to explore for subsurface sand deposits in western Lake Erie (Fig. 1) has revealed an extensive formation of well-sorted sand, presumably deposited as a delta at the mouth of the ancestral Detroit River. The following paper describes the features of this deposit and suggests a chronology for its evolution.

METHODS

The hydraulic jetting method was used to make all of the test borings; however, at a few locations supplemental cores were taken with a gravity-piston corer. The jetting method was developed by Wilson (1941) and modified by Pincus (1951). Briefly, the operation consisted of forcing water under pressure through aluminum pipe of various diameters: 5.1, 2.5, and 1.3 cm. The pipe was worked up and down as the water washed out the sediment. Additional lengths of pipe were added until the desired depth of penetration was reached. The 5.1 cm pipe generally penetrated unconsolidated silt, clay, sand, and fine gravel, but in many cases met refusal in compact clay, medium gravel, and glacial till, and always at the bedrock surface. The 2.5 cm or 1.3 cm pipe was then placed inside the 5.1 cm pipe to penetrate clay, till, and medium gravel, but these smaller tubes met refusal in coarser material. Core samples were then taken at any desired depth with a 1.9 cm hollow-tube check-valve sampler. The sampler was directed downward inside the 5.1 cm pipe and driven into the subsurface material by hand. Cores up to 0.9 m in length were obtained by this method. Normally, one core sample was taken for every 1.5 m of bottom penetration. Samples that occasionally came up the pipe between the 5.1 cm and smaller diameter pipe and the resistance of the bottom material to penetration also provided information on the character of the sediments. The cores were measured and described in the field and then stored in glass jars or plastic wrap for laboratory analysis. In most cases borings were completed to the bedrock surface.

All test borings and cores were taken from aboard the Ohio Department of Natural Resource, Division of Geological Survey's 14 m research vessel, GS-1. On station, this vessel was held in position by a three-point anchoring system. Horizontal control was obtained by sextant sightings on charted landmarks. Vertical control was obtained from water-level gages at Put-in-Bay and Sandusky, Ohio and referenced to International Great Lakes Datum.

RESULTS

A total of 50 test borings were made into the sediments of western Lake Erie in the vicinity of Middle Sister Island (Fig. 2). They revealed a sand deposit covering an area of approximately 550 km² (212 mi²). The deposit averages 2.3 m (7.4 ft) in thickness, yielding a volume of 2.2×10^9 m³.

The cross-section in Fig. 3 depicts the unconsolidated sediments between Stony Point, Michigan, and Middle Sister Island, Ontario, as interpreted from 16 test borings. The general sequence of deposits overlying the bedrock (River Raisin Dolomite: of Silurian Age) is: glacial till, glaciolacustrine sediments, deltaic sand and gravel beds, and recent muds. The bedrock surface shows 23 m (74 ft) of relief from the rock exposed at the shores (I-200 and I-215, elevations around 171 m above sea level) to the bottom of a supposed preglacial drainage channel (I-204). At its lowest point, the rock channel has an elevation of approximately

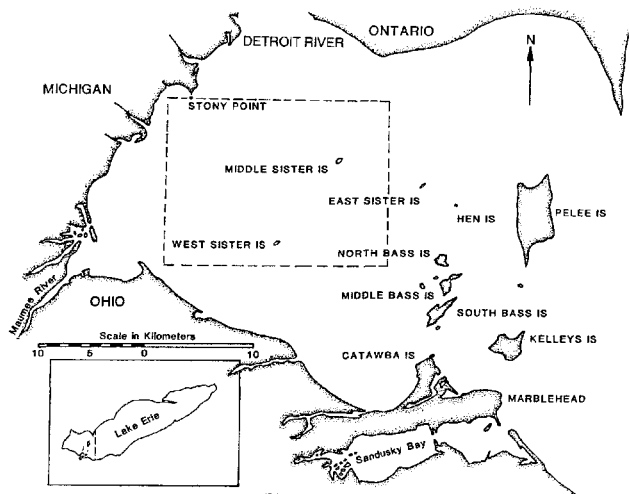


Figure 1. Location of Study Area in Western Lake Erie.

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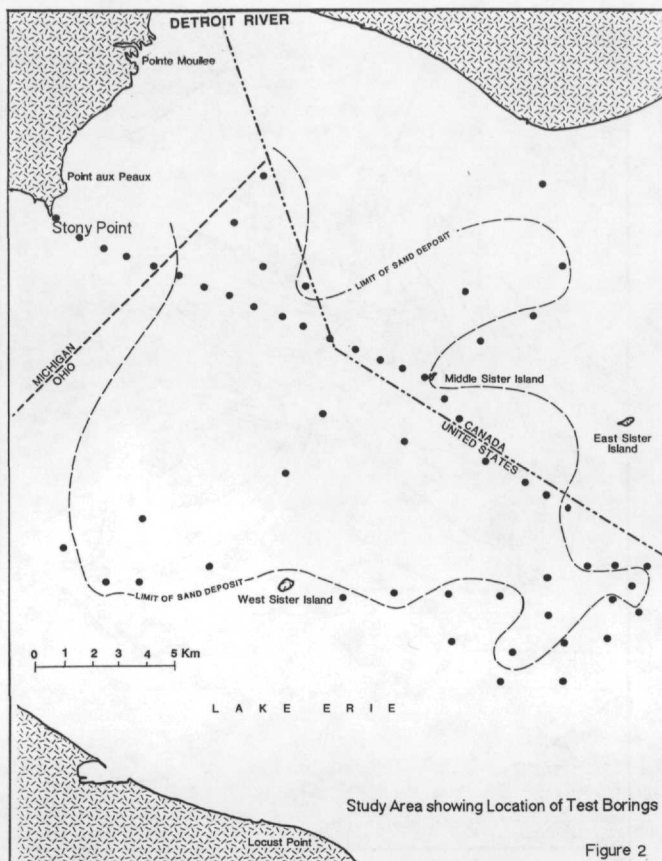


FIGURE 2. Study area showing location of test Borings and limit of sand deposit.

150 m (492 ft) above sea level (Fig. 4). The glacial till is a pebble-rich, dense, gray clay. It ranges in thickness from less than 1 m (3 ft) to about 7 m (22 ft). The upper till surface appears to conform with the bedrock surface and rises to the northeast as well as southwest from the axis of the bedrock valley. Away from the bedrock valley, the till surface generally rises from east to west, lying at an elevation of 152 m (500 ft) near Middle Sister Island (Fig. 5) and 163 m (535 ft) about 3 km (2 mi) off the Michigan shore (Fig. 3).

Glaciolacustrine sediments over the till consist of firm, brownish-gray clay. These deposits range from about 1.5 m (5 ft) to 6 m (20 ft) thick, being thinnest

where the overlying sand beds are the thickest (compare I-202 and I-203). The upper surface of the glaciolacustrine clays generally lies below an elevation of 162 m (530 ft). The sand beds are primarily well-sorted (clean), medium- to fine-grained material with some gravel. Two distinct channels, or areas of sand thickening, are discernible in the cross-section (Fig. 3). Borings I-202 and I-201 suggest a distributary channel some 3 km (2 mi) across; borings I-204, 205, and 206 indicate a channel-fill more than 5 km (3 mi) across. The sand beds in these channels have top elevations ranging from about 161 to 164 m (527-539 ft) and are not exposed on the lake bottom except in the southwestern portion of the study area. They are typically overlain by 0.3 to 2.4 m (1-8 ft) of recent muds. These muds consist of soft, semi-fluid, silt- and clay-sized particles.

The dominant material in the deltaic beds is clean, medium- to fine-grained, moderately well-sorted sand (Fig. 6). Thickness ranges from 0 to 6 m (0-20 ft) and averages 2.3 m (7.5 ft). The sand deposits are overlain by up to 7 m (23 ft) of muddy overburden, but the thickness of the overburden (Fig. 7) averages only 1.4 m (4.6 ft). The development potential of these beds will be discussed later in this paper.

Extensive deposits of peat and plant detritus were found south and east of the sand beds in a silt-clay matrix between the glaciolacustrine clays and the recent muds. Herdendorf and Braidech (1972) found these materials at 57 boring stations in the islands region of western Lake Erie at elevations ranging from 172 to 156 m (563-513 ft) with a mean elevation of 164 m (537 ft). Core samples from this zone average about 12% volatile solids. Five radiocarbon dates ranging from 4,335 to 9,440 years B.P. were obtained on the peaty material (Table 1). Herdendorf and Braidech interpreted these deposits to represent a post-glacial low-water stage when only shallow lakes or wetlands were present in western Lake Erie. Lewis et al. (1966) reported a radiocarbon date of 11,300 years B.P. for a similar deposit north of the islands. When the range of all dates is considered, it appears likely that the western basin stood dry at elevations above 161 m (528 ft), except for possible wetlands, for at least 7,000 years. Following this dry period, the lake basin became flooded again about 4-5,000 years ago.

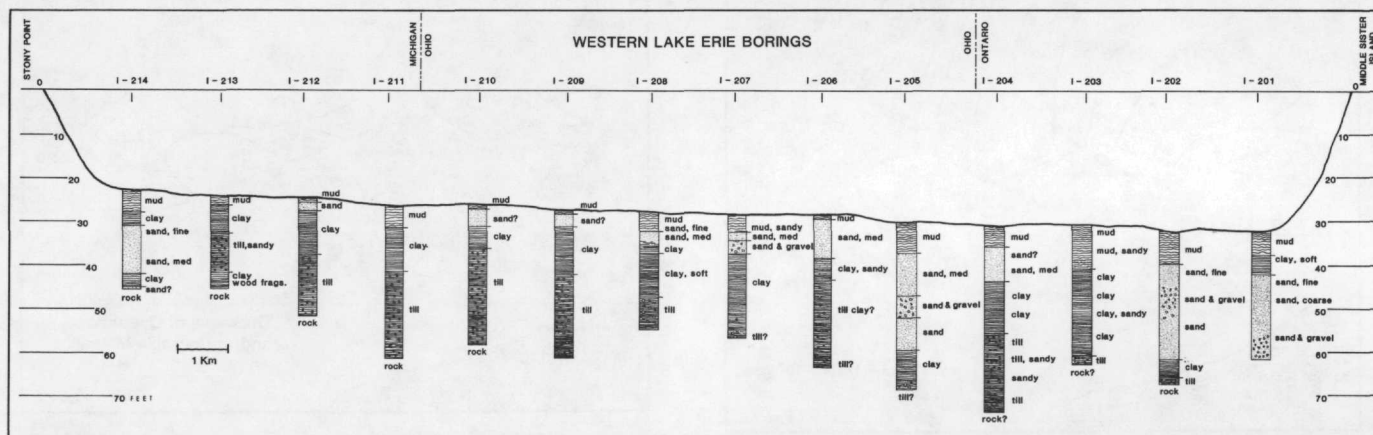


FIGURE 3. Cross-section through unconsolidated deposits between Stony Point, Michigan, and Middle Sister Island, Ontario, western Lake Erie.

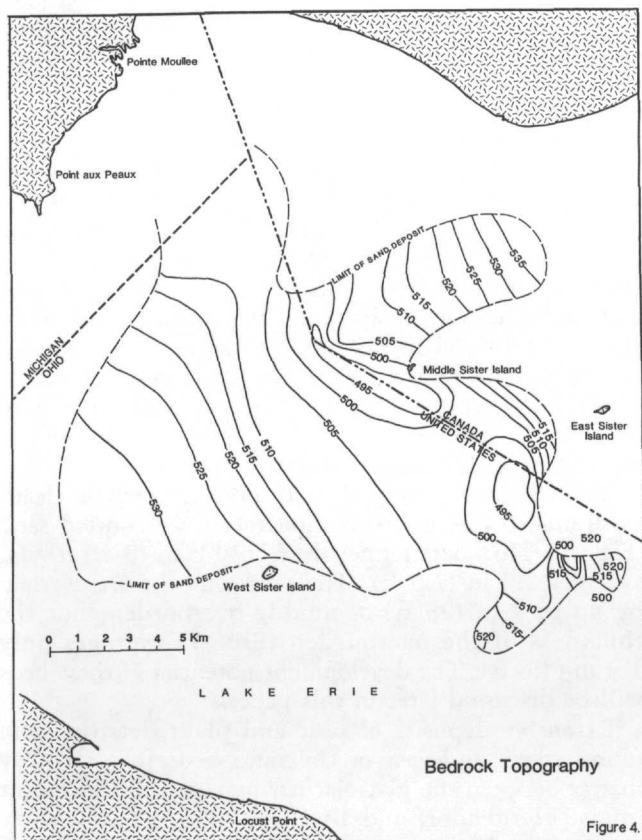


FIGURE 4. Bedrock topography in the vicinity of the ancestral Detroit River delta. Contours are in feet above sea level.

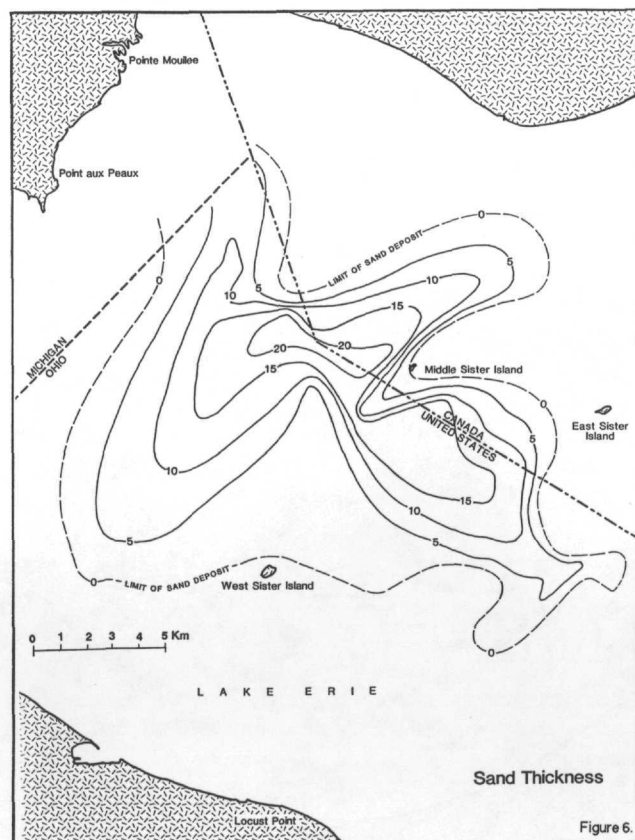


FIGURE 6. Sand thickness (feet) in vicinity of the ancestral Detroit River delta.

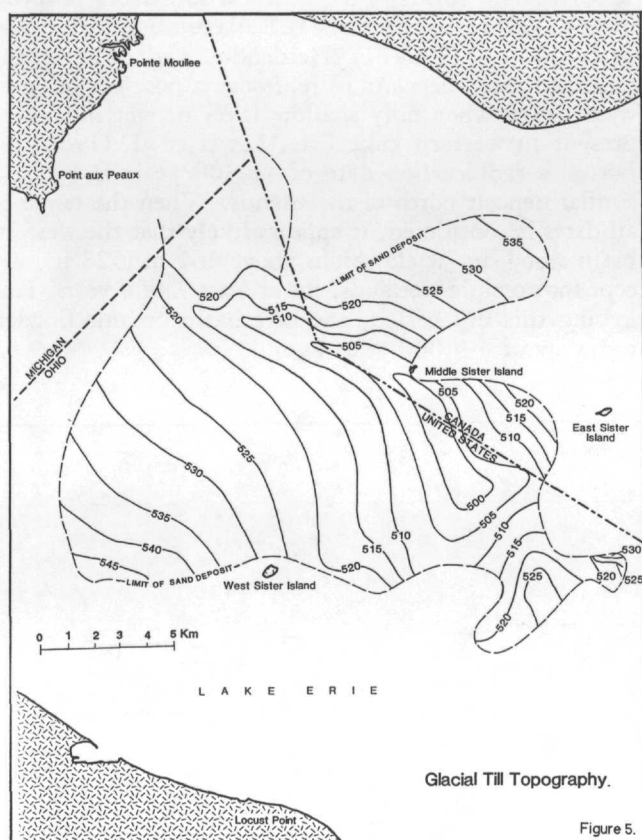


FIGURE 5. Glacial till surface topography in the vicinity of the ancestral Detroit River delta. Contours are in feet above sea level.

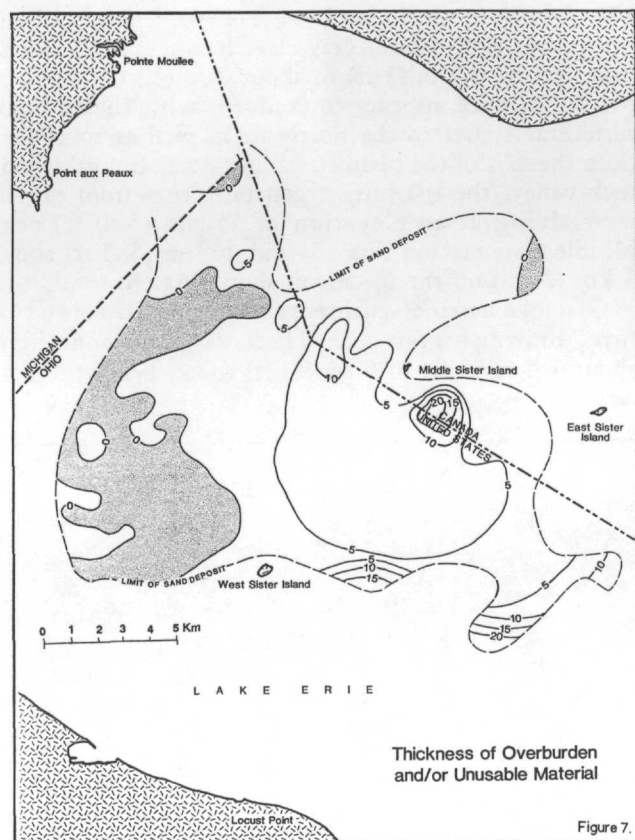


FIGURE 7. Thickness (feet) of recent muds overlying sand deposit in the vicinity of the ancestral Detroit River. Stippled areas indicate surface sand deposits.

TABLE 1
Radiocarbon dates on plant detritus in sediment cores from northwest of the Bass Islands, Western Lake Erie.

Core station	Water depth	Sediment penetration	Elevation	Radiocarbon date (years B.P. \pm 1 SD)	Lab no.
WR-31 Lat. 41°40.7' Long. 82°55'	9.3 m (30.4 ft)	3.3 m (10.7 ft)	160.8 m (527.5 ft)	4,335 \pm 135	OWU-318
WR-32 Lat. 41°41.6' Long. 82°55'	9.3 m (30.5 ft)	3.2 m (10.6 ft)	160.8 m (527.5 ft)	9,115 \pm 210	OWU-319
WR-33 Lat. 41°42.4' Long. 82°55'	9.5 m (31.2 ft)	3.0 m (10.0 ft)	160.7 m (527.4 ft)	9,440 \pm 315	OWU-350
WR-34 Lat. 41°43.3' Long. 82°55'	9.6 m (31.6 ft)	2.9 m (9.5 ft)	160.8 m (527.5 ft)	5,097 \pm 175	OWU-351

Data source: Herdendorf and Braidech (1972).

DISCUSSION

Lake Erie owes its origin to physiographic changes induced by Pleistocene glaciation of a pre-existing drainage system. As the ice sheet paused in its advance or retreat, morainic ridges of till were built up at its margin, damming the former drainage and forming a series of large glacial lakes. As the ice retreated, new and lower outlets were uncovered and new lake stages were formed at successively lower levels, except for minor readvance. Modern Lake Erie is a remnant of this process.

Approximately 12,500 years B.P. the ice margin retreated northward from the Erie basin, uncovering a new drainage outlet via the Niagara River. At that time, however, the Niagara sill was about 30 m (100 ft) lower than present due to the depression of the crust by the weight of the approximately 2-km-thick glacier (Lewis et al. 1966). Thus, this lower outlet caused a massive flood of water to exit the Erie basin (Forsyth 1973), resulting in the drainage of the western end of the lake, and the formation of separate, shallow lakes in the central and eastern portions of the lake basin. This initiated the Early Lake Erie phase (Fig. 8) by dropping the lake surface to about 143 m (470 ft) above sea level (Hough 1958 and 1966, Lewis et al. 1966, Coakley and Lewis 1985).

Initially, Early Lake Erie received discharge from Lake Algonquin via the newly formed St. Clair River, Early Lake St. Clair, and the Detroit River system

(Leverett and Taylor 1915, Dreimanis 1964 and 1969). Calkin and Feenstra (1985) pointed out that the ensuing rapid rise in Lake Erie's level resulting from differential glacioisostatic uplift of the Niagara sill, was soon interrupted for the first time as Lake Algonquin outflow from the Huron basin by-passed Lake Erie via the Kirkfield outlet to the Ontario basin (about 11,800 years B.P.). Despite this cessation of inflow from the upper basins, uplift of the Niagara sill continued to slowly raise the level of Early Lake Erie.

The return of the drainage from the upper basins, caused by continued glacial uplift north of Lake Erie, corresponded to the Nipissing stage in the Huron basin at about 5,000 years B.P. (Calkin and Feenstra 1985). This event appears to have given impetus to the formation of the deltaic deposits of the mouth of the ancestral Detroit River. Seismic profiles indicated that the contact between the till and the glaciolacustrine clay lies at an elevation below 157 m (515 ft) in much of the delta region and eastward to Pelee Passage into central Lake Erie (Hobson et al. 1969, Fig. 4). Because the thickness of the clays over the till is generally less than 3 m (10 ft) in this part of the basin, a natural depression would have been available as a pathway to the delta region as soon as the lake reached an elevation of 160 m (525 ft). Fig. 9 illustrates the probable configuration of Early Lake Erie at this time.

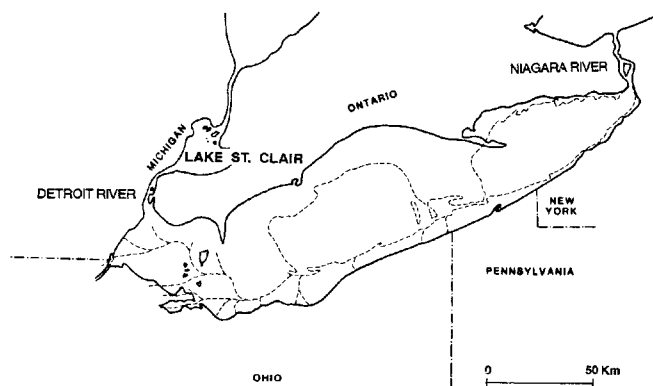


FIGURE 8. Schematic reconstruction of Erie basin drainage system at the time of Early Lake Erie (dashed) relative to present system.

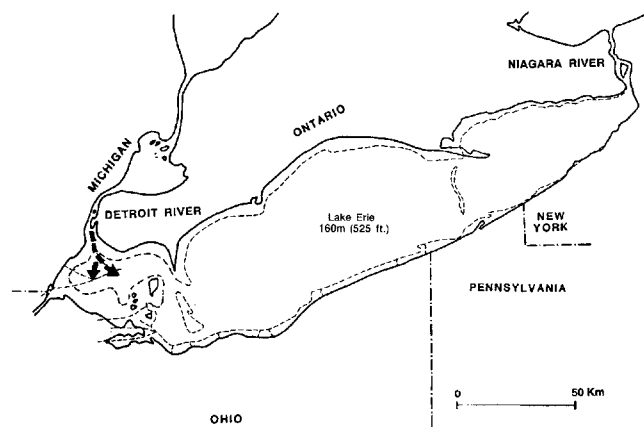


FIGURE 9. Schematic reconstruction of Early Lake Erie at the inception of the ancestral Detroit River delta.

To understand the depositional history of the Detroit River delta it is instructive to consider the sequence of events which created the St. Clair River delta. Raphael and Jaworski (1982) studied the origin of the St. Clair River delta and determined that two distinct levels of deltaic deposition exist: (1) a premodern surface standing about 1.5 m (5 ft) above Lake St. Clair, composed of coarse sand, and (2) a modern delta located at the present mean lake level, consisting of silty sand (Fig. 10). Radiocarbon dates from underlying lacustrine clays indicated that both levels are less than 7,300 years old. They postulated deposition of the premodern delta during Nipissing time (3,500-5,000 years B.P.) and not during Algonquin time (10,500-12,500 years B.P.), as had been ascribed by earlier investigators (Flint 1964). The more recent date suggested by Raphael and Jaworski appears to correspond with the depositional period of the Detroit River delta. Following the low water stage of Lake Stanley (5,000-10,500 years B.P.) in the Huron Basin, the level rose to the Nipissing stage and the St. Clair River once again flowed south into Lake St. Clair. Thus, the premodern delta was deposited at an elevation slightly higher than the modern delta. Erosion of the connecting channels between Lake Huron and Lake Erie, particularly the Detroit River, probably accounts for the lowering of Lake St. Clair to its present level and the formation of the modern delta surface.

During the low-water period of Early Lake Erie, at least one other large delta-like feature was formed. Hartley (1960) reported the existence of a massive deposit of sand in the central basin offshore from the for-

mer mouth of the Grand River in Lake County, Ohio (Fig. 11). This deposit consists of well-sorted, medium-grained sand. The sand beds are up to 14 m (45 ft) thick and have an inshore surface elevation of 163 m (534 ft) and an offshore bottom elevation of 141 m (464 ft). Based on the clean, well-sorted character of the sand, Hartley concluded that the deposit was not a glacial moraine but more likely the result of deltaic deposition and persistent littoral processes beginning at an extremely low lake elevation and continuing through a long period of gradually rising levels. The Detroit River delta and the upper portion of the Grand River delta lie at approximately the same elevation, indicating a contemporaneous period of formation. The lower portion of the Grand River delta probably started to form earlier, when lake level was lower, and before the reflooding of the western basin.

Based on the subsurface information presented by Raphael and Jaworski (1982), an estimated $1.8 \times 10^9 \text{ m}^3$ of sandy sediment has been deposited in Lake St. Clair to form the St. Clair River delta. Considering the relative lengths of the St. Clair River channel and the Detroit River channel, this quantity compares reasonably well with the $1.3 \times 10^9 \text{ m}^3$ of sand calculated for the Detroit River delta. The smaller Grand River delta in central Lake Erie contains $3.6 \times 10^8 \text{ m}^3$ of sand, or about one-fourth of the volume of the Detroit River delta.

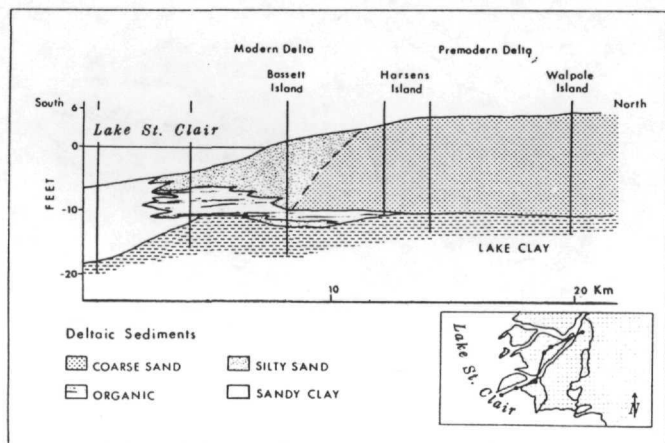
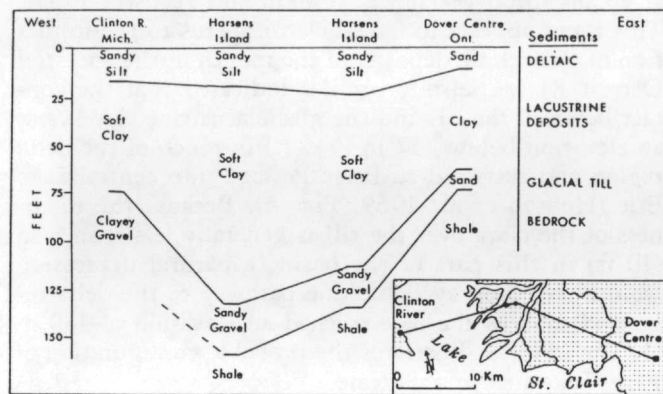


FIGURE 10. Cross-sections through unconsolidated deposits in the St. Clair River delta (from Herdendorf et al. 1986) based on drilling records.

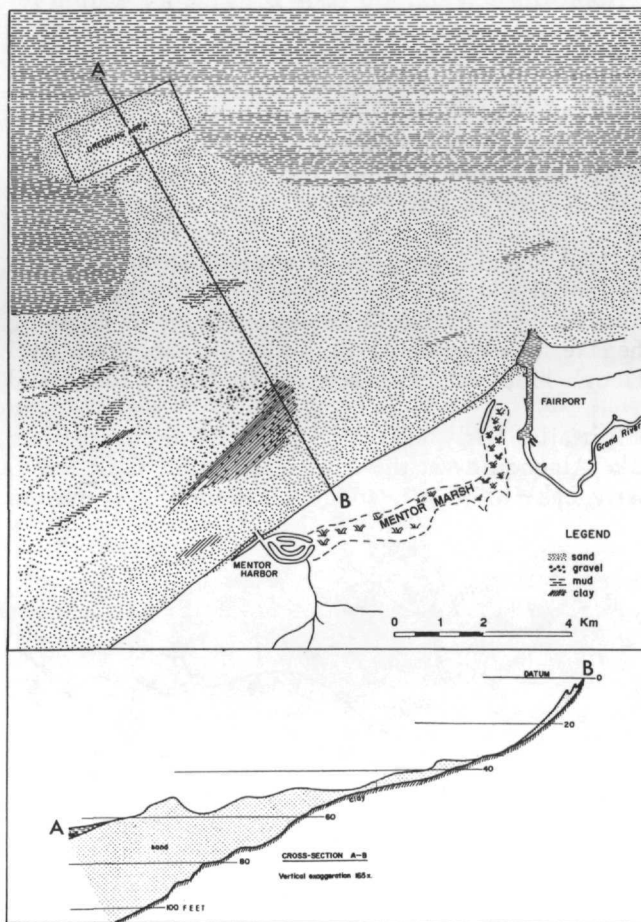


FIGURE 11. Surface map and cross-section of unconsolidated deposits in Grand River delta, central Lake Erie (from Hartley 1960). Vertical scale in feet.

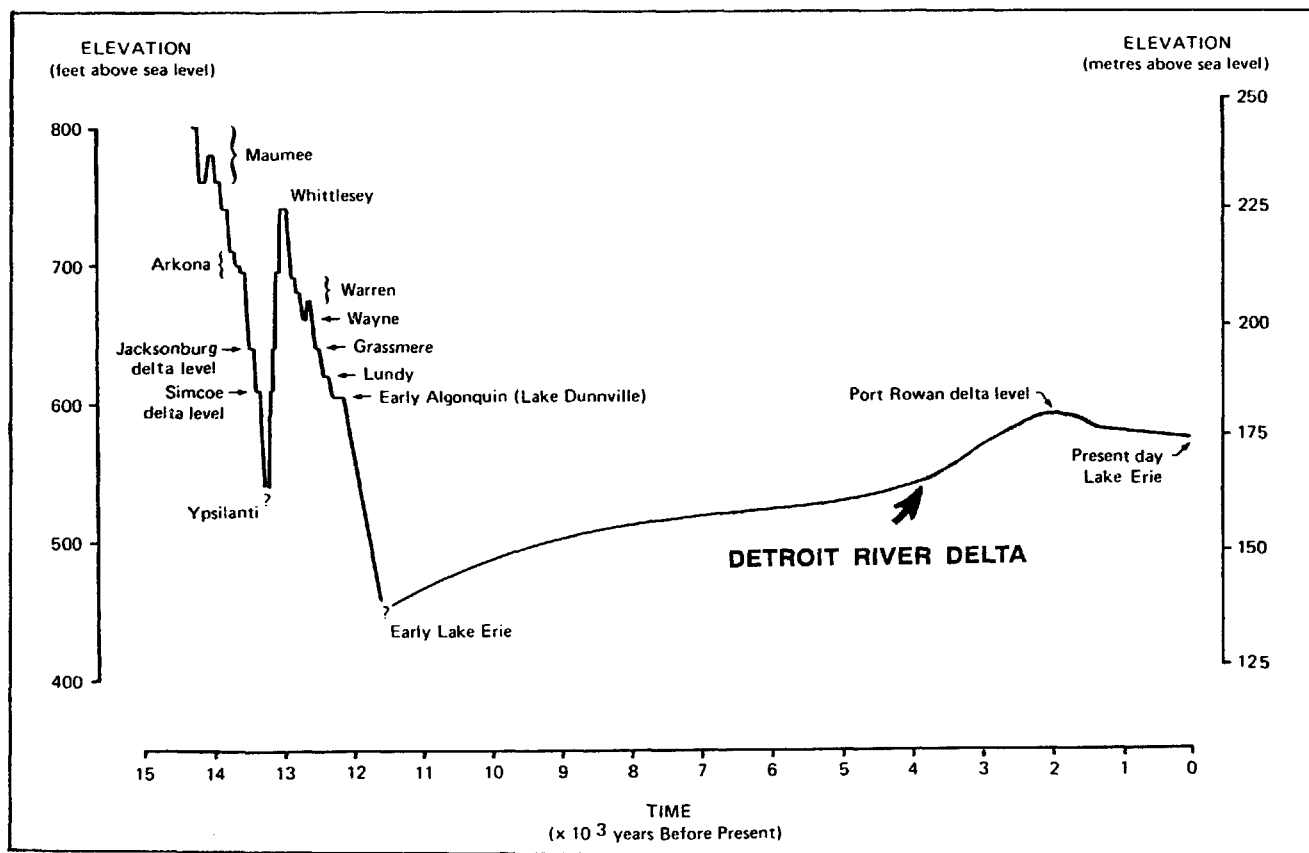


FIGURE 12. Sequence of ancestral lakes in the Lake Erie basin showing the proposed time of inception of the Detroit River delta (modified after Barnett 1985).

In considering the possible source of the material in the Detroit River delta, an obvious prospect is the Detroit River channel cut in glacial drift from Peach Island at the river's Lake St. Clair head to Bar Point at its mouth on Lake Erie. The quantity of material that had to be eroded to create the channel, assuming an average water depth of 7 m (23 ft) and a bluff height of 3 m (10 ft), is approximately $0.8 \times 10^9 \text{ m}^3$. An additional $0.2 \times 10^9 \text{ m}^3$ can be added from the excavation of 11 m (35 ft) high Detroit Interlobate Moraine (Leverett and Taylor 1915). Not all of this material was coarse enough to build the delta, but considering the additional material that was cut to form the flood plain south of the moraine and the valleys of the tributaries (i.e., River Rouge, River aux Canards, and Huron River), enough sand can be accounted for to create a delta of this size.

CONCLUSIONS

The Lake Erie basin experienced a low water stage from approximately 12,000 to 4,000 B.P. During this low lake stage, much of the western basin was dry while drainage from the upper Great Lakes basins bypassed Lake Erie and flowed to the Lake Ontario basin via the Kirkfield and Ottawa river outlets. The Niagara sill gradually rebounded from an elevation of about 143 m (470 ft) to about 158 m (520 ft) permitting the lake to once again flood the northern portion of the western basin. At about the same time, isostatic rebound closed the Kirkfield outlet, and drainage from the Huron basin (Lake Nipissing stage) via the St. Clair-

Detroit river system was permanently established. The premodern delta of the St. Clair River was formed as a result (Raphael and Jaworski 1982). It is postulated that deposition of the ancestral Detroit River delta in western Lake Erie also occurred at this time (about 4,000 years B.P.). Eventually Lake Erie rose an additional 15 m (50 ft) to its present level, flooding the delta and permitting the deposition of recent muds over the deltaic sands (Fig. 12).

The dominant material in the deltaic beds is clean, medium- to fine-grained, moderately well-sorted sand (Fig. 6). Thickness ranges from 0 to 6 m (0-20 ft) and averages 2.3 m (7.5 ft). The sand deposits are overlain by up to 7 m (23 ft) of muddy overburden (commercially unusable material), but the thickness of the overburden (Fig. 7) averages only 1.4 m (4.6 ft). Unfortunately, some of the thickest overburden overlies the thickest sand beds. Preliminary assessment of the deltaic deposits indicates that they have a good commercial extraction potential. The development potential of these deposits is enhanced by the relatively shallow water depths (about 10 m), soft overburden, non-littoral nature of the beds, and a location well offshore from critical aquatic habitats.

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